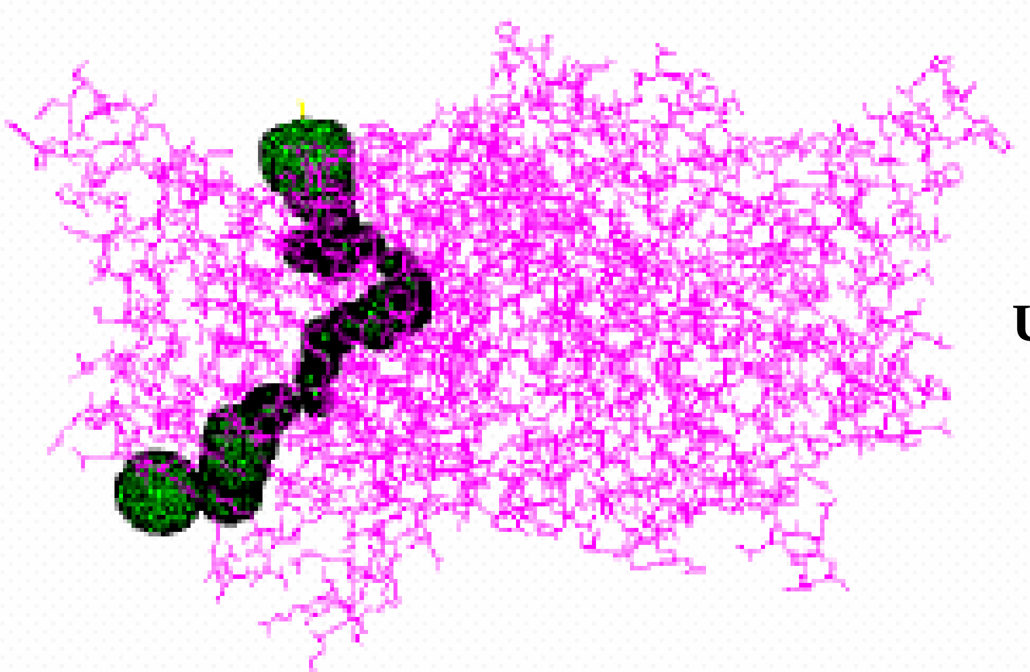
Nanotechnology and Long-Term Implantable Devices

Army Research Office Overview

2007 TATRC IRT



Dr. David M. Stepp
Materials Science Division
US Army Research Office
US Army Research Laboratory

919-549-4329
david.m.stepp@us.army.mil
http://www.aro.army.mil

24 October 2007

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **24 OCT 2007**	2. REPORT TYPE	3. DATES COVERED **00-00-2007 to 00-00-2007**

4. TITLE AND SUBTITLE **Nanotechnology and Long-Term Implantable Devices. Army Research Office Overview**	5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **US Army Research Office,US Army Research Laboratory,Materials Science Division,Research Triangle Park,NC,27709-2211**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S) 11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Integrated Research Team (IRT) Meeting ?Nanotechnology Solutions for Long-term Implantable Devices? Oct 23-25, 2007

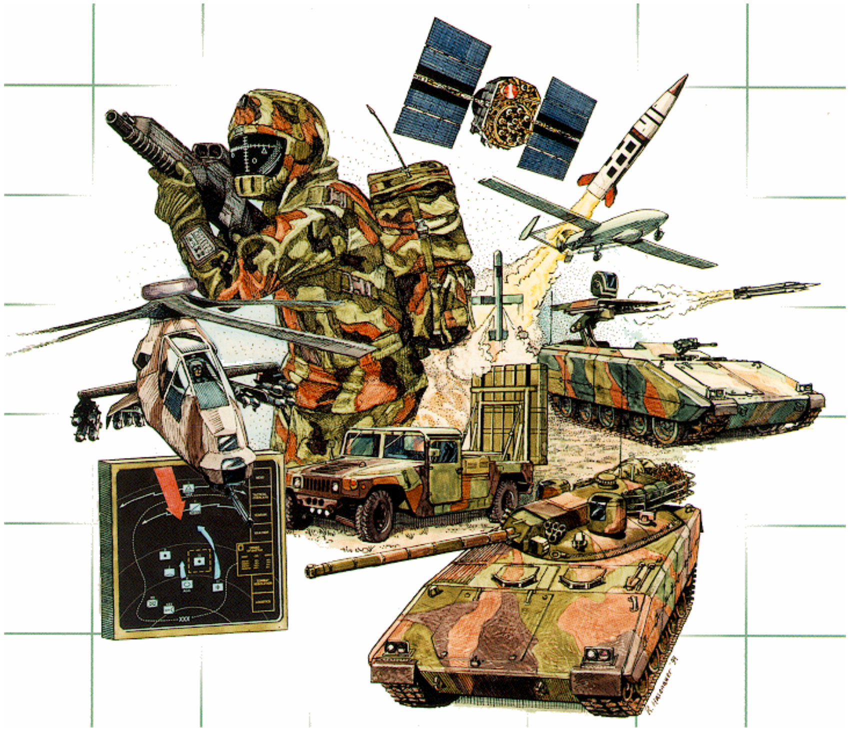
14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**11**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

ARO Materials Science Vision:
UNPRECEDENTED MATERIAL PROPERTIES



The US Army materials science basic research investment seeks to provide new innovations in materials design and processing to enable advanced materials for improvements in firepower, mobility, armaments, communications, personnel protection, and logistic support.

Basic Research Goal: The Soldier of 2032

(Unprecedented Material Properties)

ARO Materials Science Focus Areas

http://www.aro.army.mil

Mechanical Behavior of Materials

- High strain-rate phenomena
  - Characterization tools
  - Lightweight energy absorption
- Materials enhancement theory
  - Property-processing relationships
  - Specific toughness
- **Tailored functionality**
  - **Active transport membranes**
  - **Self-assembling architectures**

Synthesis and Processing

- Electromagnetic field effects
  - Difficult to process materials
- **Supramolecular scaled materials**
  - **Bulk submicron-scale microstructures**
  - **Molecular-scale composites**
  - **Functional mesoscale structures**
  - **Directed assembly strategies**
- Bulk metallic glasses
  - Processing bulk structures
  - Local structure-property relationships

Design of Materials

- **Growth and processing design**
  - **Surface & interface engineering**
  - **Nonequilibrium processing**
  - **Embedded monitoring**
- In-situ to nanoscale characterization
  - Property control
  - High resolution spectroscopy

Physical Properties of Materials

- Defect engineering
  - Heteroepitaxy & liftoff
  - Defect formation
  - Nanoscale characterization
- **Functional materials**
  - **Nanostructuring of materials**
  - **Multifunctional materials**

ARO Life Sciences Focus Areas (Neuroscience)

http://www.aro.army.mil

- **<u>Neuroergonomic/neuromorphic computing</u>**
  - Define how the brain processes and refines inputs into efficient decisions in order to create automated systems that optimally enhance Soldier capabilities
  - Explore other species' sense/computing capabilities for novel algorithms usable in automated/remote military systems
- **<u>Bioadaptive Soldier status monitoring</u>**
  - **Exploit new non-invasive physiological techniques to measure and predict Soldier cognitive and physiologic state**
- **<u>Bidirectional equipment bio-interfaces</u>**
  - **Define the informational bandwidth capability of the Soldier across multiple simultaneous sensory modalities**
  - **Develop methods to "close the loop" between Soldier status and military equipment (auto-adaptive displays and controls)**

DoD Nanotechnology Perspective

- **Definition:** to develop understanding and control of matter at dimensions of approximately 1 to 100 nanometers, where the physical, chemical, and biological properties ***differ*** in fundamental and valuable ways from those of individual atoms, molecules, or bulk matter
- Nano-hype
- National Nanotechnology Initiative (NNI) accelerates high-potential nanotechnology-based capabilities:

  Chemical/biological defense; Information technology; Energy and energetics; Multifunctional materials and devices; Health monitoring, sensing, and care

Cross-Cutting Biomaterials Themes

- **Embedding biological functionality in synthetic materials**
  - Unique and specifically designed biological functionalities and activities
  - Maintaining (and preferably enhancing) requisite mechanical properties
  - Coatings, multifunctional structures, and enhanced sensors

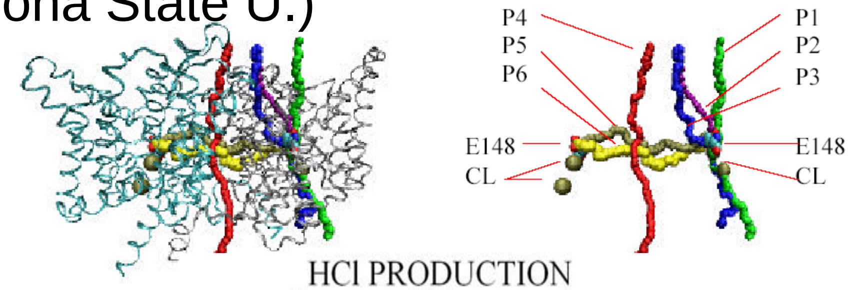
- **Bio/synthetic interfaces**
  - “Permanent” skin penetration
  - Functional links to nerve
  - Functional links to muscle
  - Functional links to bone

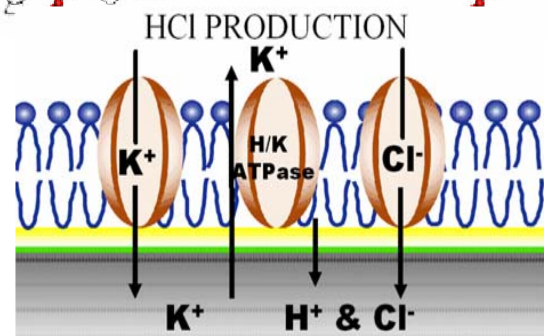
Synthetic Active Transport

(U. Cincinnati, U. Pittsburgh, Arizona State U.)

OBJECTIVE:

To produce synthetic flexible membranes containing biological transport proteins that can utilize energy for the selective uptake, concentration and release of ions and molecules in an organized manner. The effort includes production of both macroscopic membranes and nanostructures containing transport proteins with vectorial transport function.





ACCOMPLISHMENTS:

- The first ever functional ion-selective synthetic protein membrane on inorganic support has been prepared and demonstrated, providing unprecedented potential for future sensors, drug delivery, and fuel cells.
- Developed enhanced algorithm to predict transport pathways in proteins, even for very large turns; this effort identified 4 possible pathways within the bacterial Cl- channel that were later confirmed by experimental evidence.

RESEARCH TEAM:

University of Cincinnati

John Cuppoletti (Physiology and Biophysics)

T.L. Beck (Computational+Theoretical Chem.)

J. Boerio (Materials Science and Engineering)

J.Y.S. Lin (Chemical Engineering)

P.R. Rosevear (Biochemistry and Microbiology)

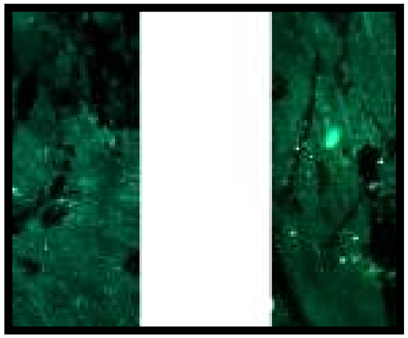
University of Pittsburgh

R. Coalson (Computational Chemistry+Physics)

Reversible E-Field Dependent Adhesion

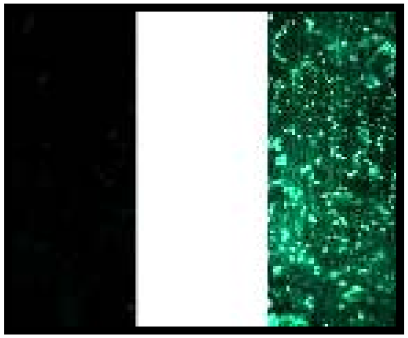
(MIT and Natick Soldier Center)

No Applied Field



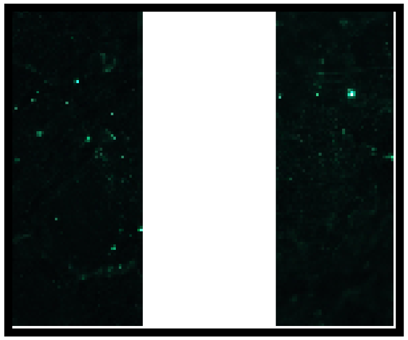
0 kV, n = 0 pulses
t = 0 seconds

Applied



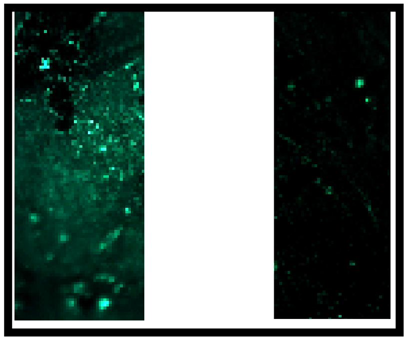
2.5 kV n = 20 Pulses
t = 5 seconds

Reversed

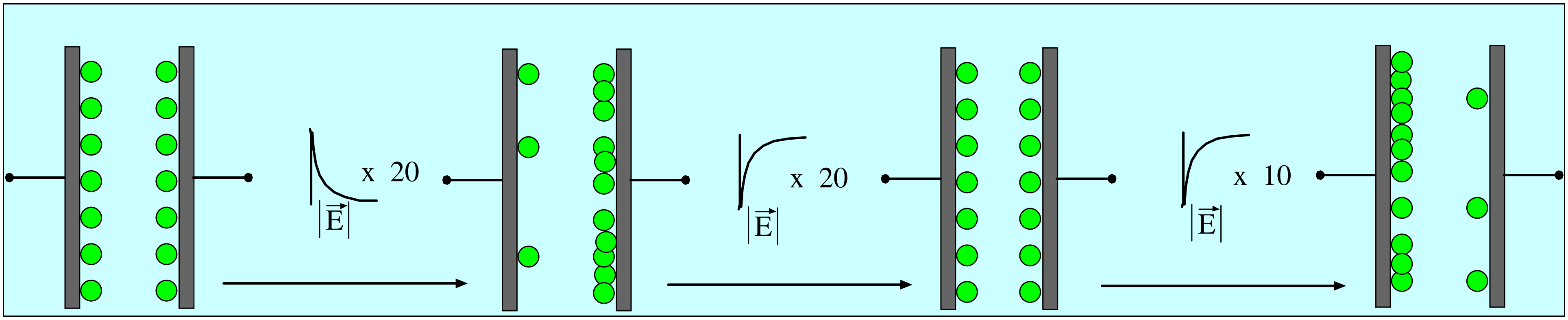


2.5 kV, n = 20
Followed by
-2.5 kV, n=20
t = 10 seconds

Reversed



2.5 kV, n = 20
Followed by
-2.5 kV, n=30
t = 15 seconds



Wearable Electrophysiologic Sensors

(QUASAR, Inc. and The Scripps Research Institute)

Objectives

- Develop EEG/ERP-based assessment of cognitive workload during performance of *Ghost Recon* (GR) (ECG to be added)
- Assessment technology does not distract subjects or impair GR performance.
- Explore correlation between GR performance, EEG measures, and performance on other simple attention tests.

EEG/ERP/ECG

↓

Cognitive overload algorithm

↓

Real-time alert or advisory signal

Approach

- Subjects perform GR at four difficulty levels: *passive* (observe GR), *easy* (4 enemies), *medium* (10 enemies), *hard* (20 enemies)
- Two attend conditions: ignore, count tones
- Spectral analysis of EEG activity
- Single-stimulus P3 ERP analyses (sparse low-level background tones elicit ERPs)

Status

- Ran 10 subjects: 4 pilot, 6 full
- Preliminary findings:
  - Game performance varied with difficulty
  - EEG alpha power decreased with difficulty
  - P3 ERP amplitude decreased and interacted with difficulty

Direct Myoneural Sensing and Control
(U. Michigan)

- Myoneural interface to the nervous system via a peripheral nerve
- New interface that a transected nerve can grow into and synapse with
  - Implantable, sensor laden tube with growing muscle cells
  - Muscle cells act as targets for the transected peripheral nerve axons
  - Allows a natural blood supply to grow into it